Image Compression
Using Wavelet Packet Tree

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Abstract—**Methods of compressing data prior to storage and transmission are of significant practical and commercial interest. The necessity in image compression continuously grows during the last decade. The image compression includes transform of image, quantization and encoding. One of the most powerful and perspective approaches in this area is image compression using discrete wavelet transform. This paper describes a new approach called as wavelet packet tree for image compression. It constructs the best tree on the basis of Shannon entropy. This new approach checks the entropy of decomposed nodes (child nodes) with entropy of node, which has been decomposed (parent node) and takes the decision of decomposition of a node. In addition, authors have proposed an adaptive thresholding for quantization, which is based on type of wavelet used and nature of image. Performance of the proposed algorithm is compared with existing wavelet transform algorithm in terms of percentage of zeros and percentage of energy retained and signals to noise ratio.**

Index Term-**Discrete wavelet transform, wavelet packet tree, percentage zero, percentage of energy retained, entropy**

I. INTRODUCTION

Visual communication is becoming increasingly important with applications in several areas such as multimedia, communication, transmission, storage of remote sensing images, education, business documents and medical images etc. Since digital images are inherently voluminous, efficient data compression techniques are essential for their archival and transmission. Discrete Wavelet Transform (DWT) has emerged as a popular technique for image coding applications [1]. DWT has high decorrelation and energy compaction efficiency. The blocking artifacts and mosquito noise are absent in a wavelet-based coder due to the overlapping basis functions [1]. The JPEG 2000 standard employs a discrete wavelet transform for image compression due to its merits in terms of scalability, localization and energy concentration [2]. JEPG 2000 suffers from blurring artifacts and ringing artifacts [3].

This paper is organized as follows. Section 2 outlines brief review of image compression. Wavelet Packet Tree is presented and described in section 3. Simulation studies based on several numerical experiments are dealt in section 4. Finally conclusion and further research directions are discussed in the section 5.

II. FUNDAMENTAL OF DIGITAL IMAGE COMPRESSION

A common characteristic of most of images is that the neighboring pixels are correlated. Therefore most important task is to find a less correlated representation of image called as compression. The fundamental components of compression are reduction of redundancy and irrelevancy. Redundancy reduction aims at removing duplication from the image. Redundancies can be spatial redundancy, spectral redundancy and temporal redundancy. In still image, the compression is achieved by removing spatial redundancy and Spectral redundancy. Irrelevancy reduction omits parts of the signal that could not be noticed by human visual system (HVS).

III. WAVELET PACKETS TREE

A. Wavelet Packets

The wavelet packet method is a generalization of wavelet decomposition that offers a richer signal analysis. Wavelet packet atoms are waveforms indexed by three naturally interpreted parameters i.e. position, scale (as in wavelet decomposition), and frequency. For a given orthogonal wavelet function, we generate a library of bases called wavelet packet bases. Each of these bases offers a particular way of coding signals, preserving global energy, and reconstructing exact features. The wavelet packets can be used for numerous expansions of a given signal.

B. Wavelets to wavelet packets decomposing.

The orthogonal wavelet decomposition procedure splits the approximation coefficients into two parts. After splitting we obtain a vector of approximation coefficients and a vector of detail coefficients both at a coarser scale. The information lost between two successive approximations is captured in the detail coefficients. Then the new approximation coefficient vector is split again. In the wavelet packet approach, each detail coefficient vector also decomposed into two parts as in approximation vector splitting.

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C. Building Wavelet Packets

The computation scheme for wavelet packets generation is easy when using an orthogonal wavelet. We start with the two filters of length 2*N*.

$$W_n(x), \qquad n=0,1,2,3$$

$$W_{2n}(x) = \sqrt{2} \sum_{k=0}^{2N-1} h(k) \, Wn\,(2-k)$$

$$W_{2n+1}(x) = \sqrt{2} \sum_{k=0}^{2N-1} g(k) \, Wn\,(2x-k)$$

$$\qquad\qquad\qquad\qquad\qquad\qquad (1)$$

$h(n)$ and $g(n)$, corresponding to the wavelet. $W_0(x) = \Phi(x)$ is the scaling function and $W_1(x) = .\Psi(x)$ is the wavelet function. An idea of wavelet packet is the same as wavelet. Only difference is that wavelet packet offers a more complex and flexible analysis. In wavelet packet analysis the details as well as the approximation are split. The wavelet packet tree for 3-level decomposition is shown in Figure 2.
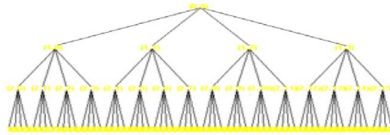

Figure 2. Wavelet Packet Tree Decomposition

In this paper Shannon entropy criteria is used to construct the best tree. Shannon entropy criteria find the information content of signal 'S'.

$$\text{Entropy}(S) = \sum_i S_i^2 \log S_i^2 \qquad (2)$$

The value of threshold is calculated based on nature of image and type of wavelet used for decomposition.
Threshold $= K - Sqrt(mean\,(w\_energy(T) \times 100))$

D. The Proposed Algorithm

The algorithm is described as follows:
1. Level counter = 1
2. The current node = input image.
3. Decompose current node using wavelet packet tree.
4. Find the entropy of the current node.
5. Find the entropy of decomposed components, CA1, CH1, CV1, CD1.
6. Compare the entropy of parent node with the sum of the entropy of child node. If the sum of the entropy of child nodes is less than that of parent node, then child node will be considered as a leaf node of a tree and repeat the steps 3, 4, 5, 6 for each child nodes considering it as current node. Otherwise parent acts as a leaf node of a tree.
7. Stop

IV. RESULTS

Wavelet packet tree using Shannon entropy has been implemented in the paper. The proposed algorithm is tested on standard testing image of size 256×256. For the implementation of the algorithm, different intensity combination images are taken. Four different images like woman, lean, cameraman and saturn are used which are rich in different patterns. Results are observed in terms of percentage of zeros, percentage of energy retained, peak signal to noise ratio and CPU time. Figure 3 shows the decompressed images after applying wavelet compression and wavelet packet tree. MATLAB simulation tool has been used for the simulation study. The performances of wavelet transform and wavelet packet tree with these four images are compared both subjectively as well as objectively.
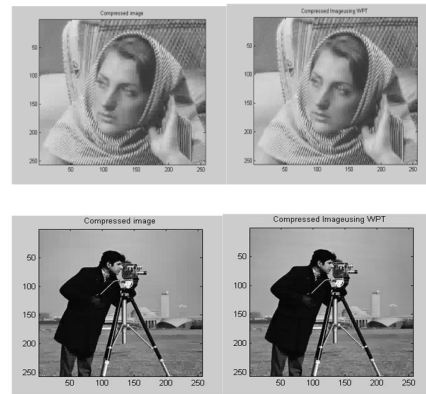

Figure 3. Decompressed Images using WT and WPT

In this work computer simulations are carried out to compare the proposed wavelet packet tree algorithm with wavelet transform algorithm using percentage of zeros, Percentage of Energy retained and PSNR value. From results shown in the table 1 it is clear that percentage of zero obtained using WPT is more than WT. It means performance of wavelet packet tree is better as compared to wavelet in terms of objective evaluation.

TABLE I: Percentage of zero after WT and WPT

Name of the Image	Percentage of zero after WT	Percentage of zero after WPT
Woman	80.5603	81.8253
Saturn	96.1829	96.2110
Lena	87.8540	87.8845
Cameraman	87.8555	87.8387

TABLE II: Percentage of Energy retained after WT and WPT

Name of the Image	Percentage of Energy retained after WT	Percentage of Energy retained after WPT
Woman	99.1948	99.2248
Saturn	99.7832	99.7864
Lena	99.5874	99.5944
Cameraman	99.7519	99.7527

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TABLE III:PSNR After WT And WPT

Name of the Image	PSNR in db after WT	PSNR in db after WPT
Woman	26.5887	27.0241
Saturn	35.8079	35.8811
Lena	30.9790	31.0530
Cameraman	31.6366	31.6503

The CPU time is the time taken for the completion of one algorithm. The program is run

on a computer with the specification of AMD 1.8 GHz processor and 1024 MB of RAM.

Table.IV. Comparison Of CPU Time Using Wt And Wpt

CPU Time	WT	WPT
In second	554.6	311.54

From the table it is shown that the WPT requires about 311 second for training. But for implementing WT it needs about 554 second.

V.CONCLUSION

In this paper the results of discrete wavelet transform and wavelet packet tree are compared. The results show that WPT is better than WT both subjectively as well as objectively. Future work includes introduction of different operators in the proposed algorithm which allow better exploration and exploitation of the search space when applied to compression. Its adaptive capacity has to be studied and generalization of this algorithm is to be done for developing more effective algorithm for image compression.

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